FIG. 1

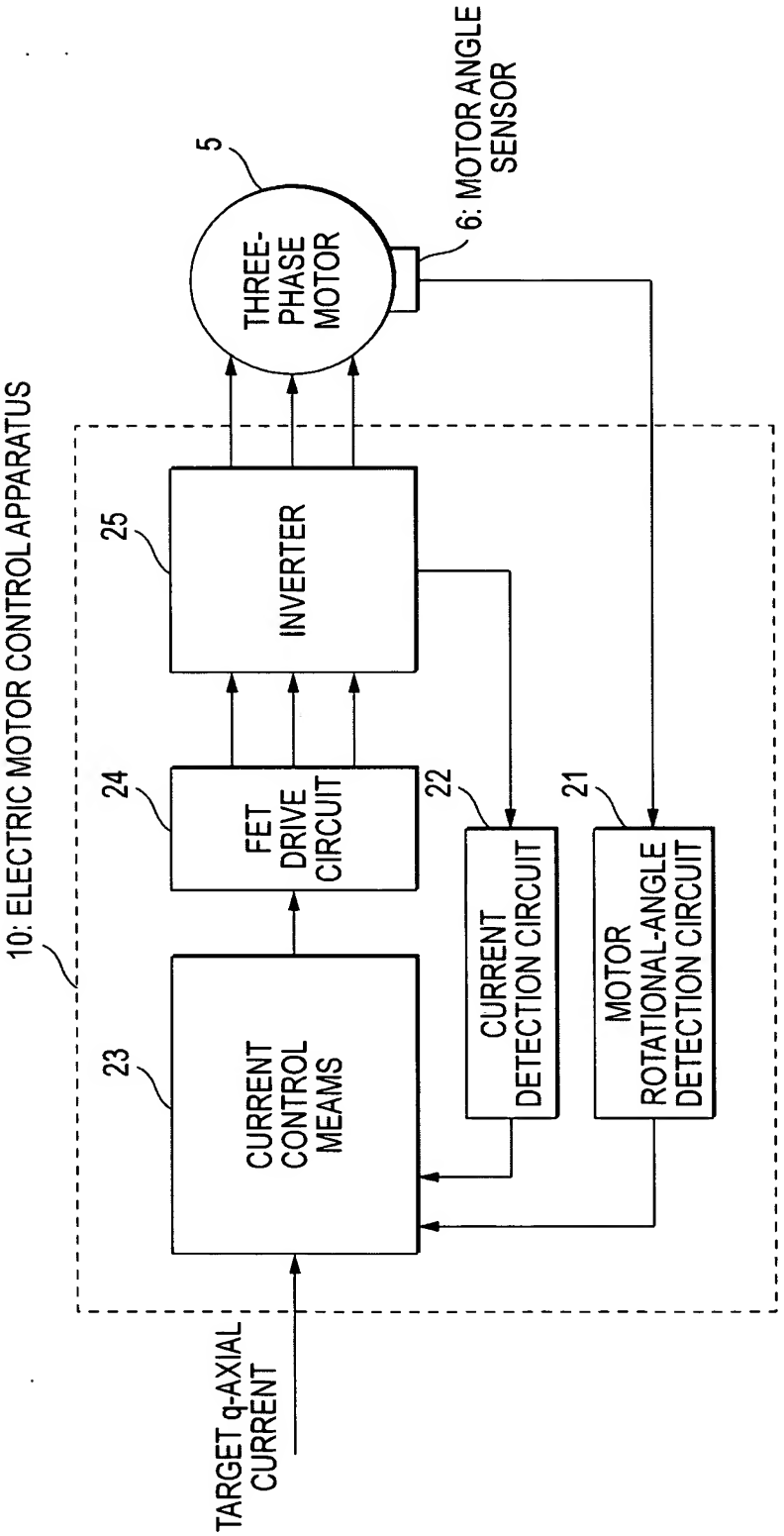

5
THREE-PHASE MOTOR
6: MOTOR ANGLE SENSOR
10: ELECTRIC MOTOR CONTROL APPARATUS
25
INVERTER
24
FET DRIVE CIRCUIT
22
CURRENT DETECTION CIRCUIT
21
MOTOR ROTATIONAL-ANGLE DETECTION CIRCUIT
23
CURRENT CONTROL MEAMS
TARGET q-AXIAL CURRENT

FIG. 2

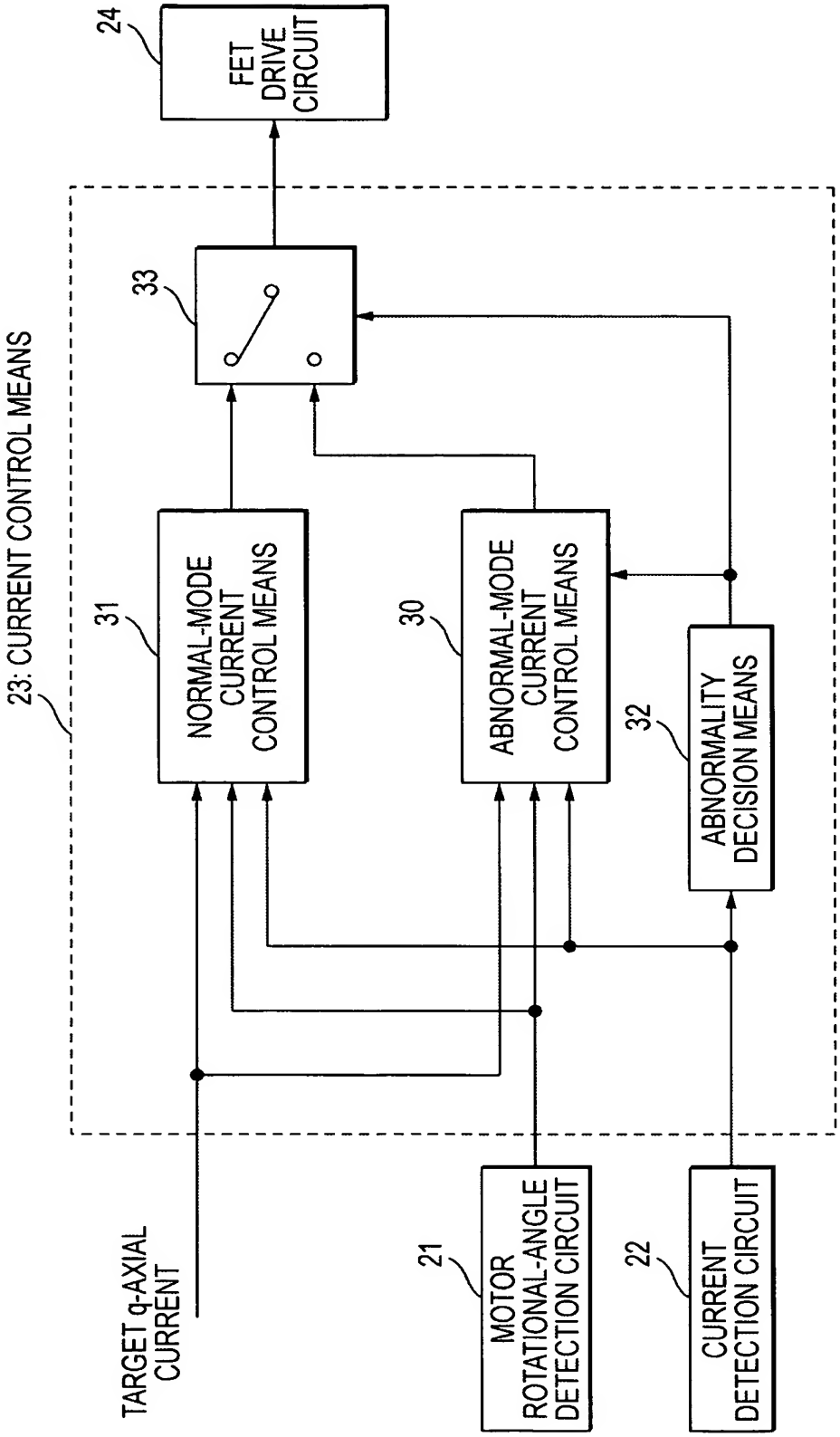

24
FET DRIVE CIRCUIT
33
23: CURRENT CONTROL MEANS
31
NORMAL-MODE CURRENT CONTROL MEANS
30
ABNORMAL-MODE CURRENT CONTROL MEANS
32
ABNORMALITY DECISION MEANS
TARGET q-AXIAL CURRENT
21
MOTOR ROTATIONAL-ANGLE DETECTION CIRCUIT
22
CURRENT DETECTION CIRCUIT

FIG. 3

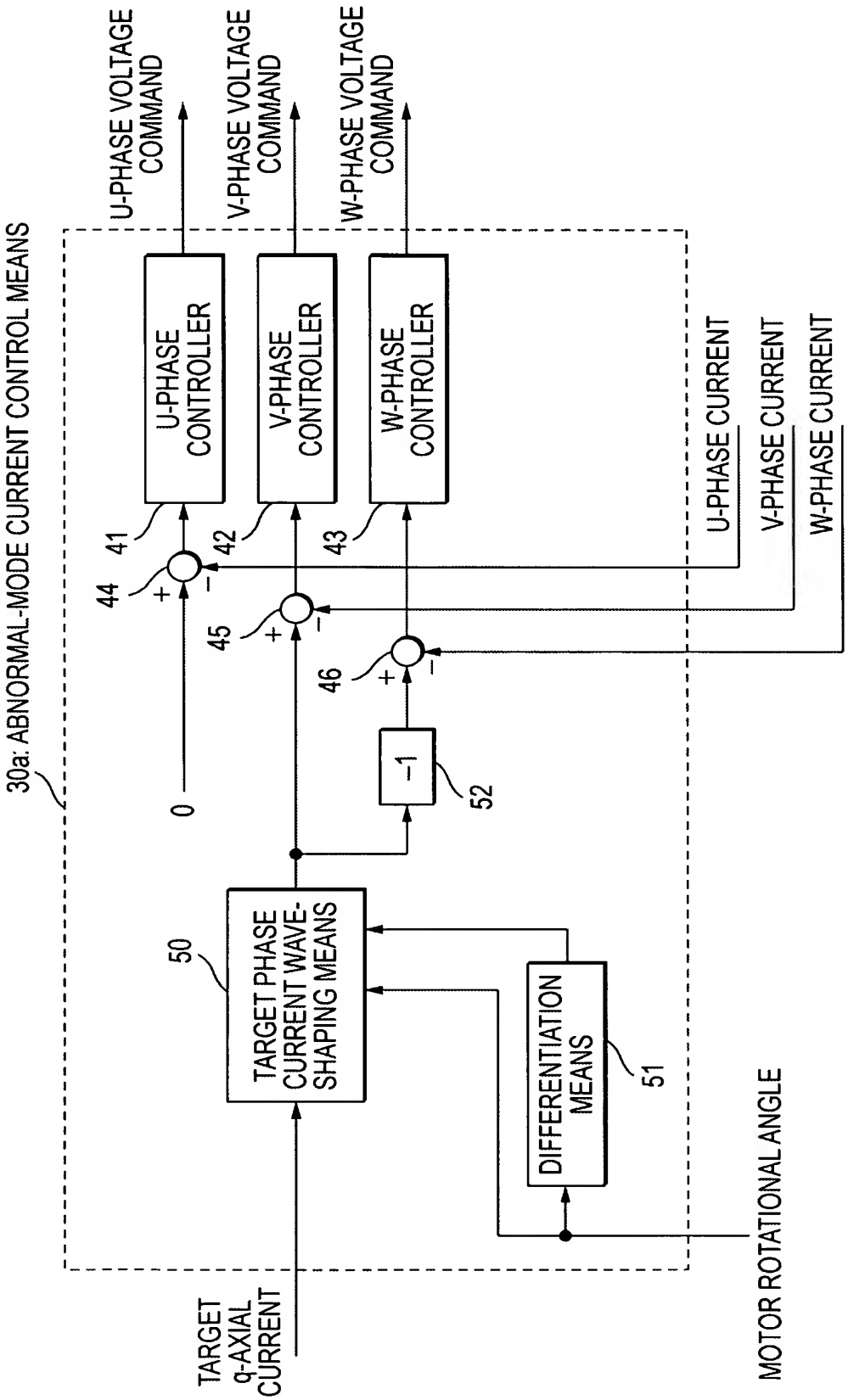

30a: ABNORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND
V-PHASE VOLTAGE COMMAND
W-PHASE VOLTAGE COMMAND
U-PHASE CONTROLLER
V-PHASE CONTROLLER
W-PHASE CONTROLLER
41
42
43
44
45
46
0
-1
52
50
TARGET PHASE CURRENT WAVE-SHAPING MEANS
DIFFERENTIATION MEANS
51
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
TARGET q-AXIAL CURRENT
MOTOR ROTATIONAL ANGLE

FIG. 4

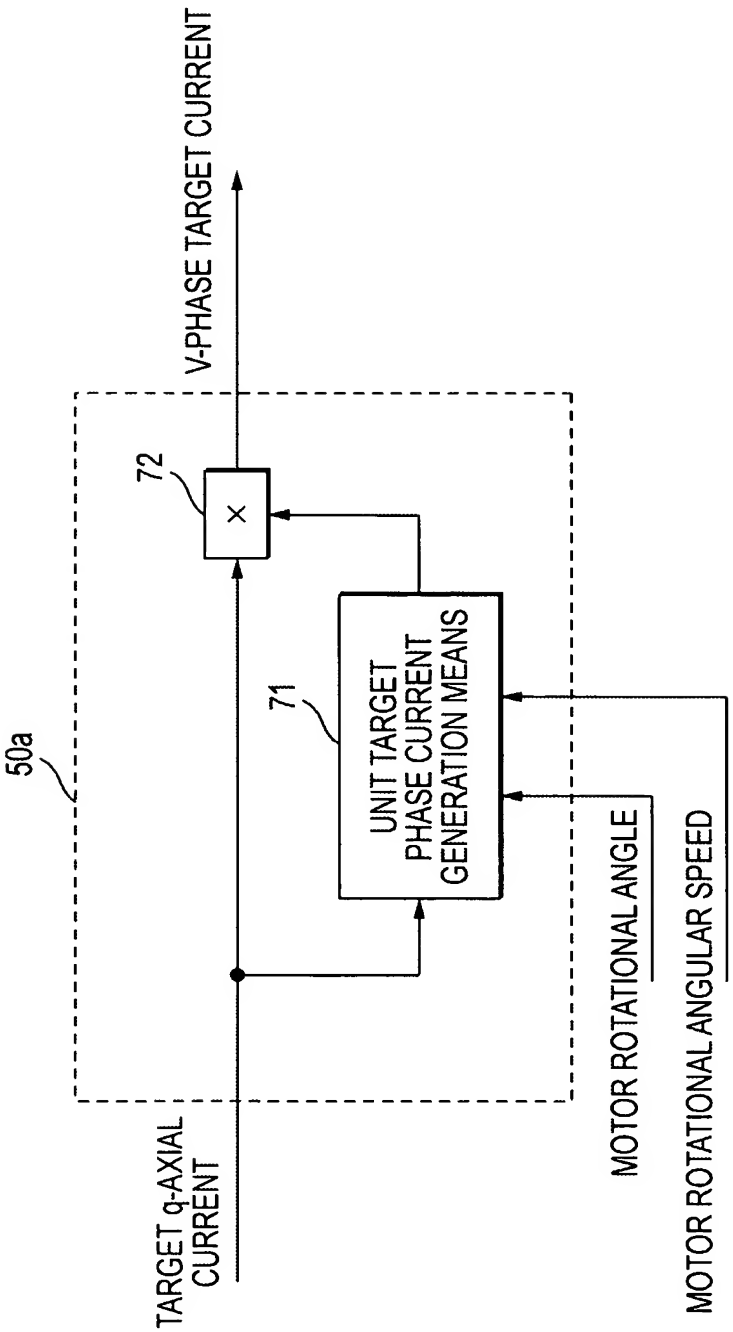

V-PHASE TARGET CURRENT
72
×
71
UNIT TARGET PHASE CURRENT GENERATION MEANS
50a
TARGET q-AXIAL CURRENT
MOTOR ROTATIONAL ANGLE
MOTOR ROTATIONAL ANGULAR SPEED

FIG. 5

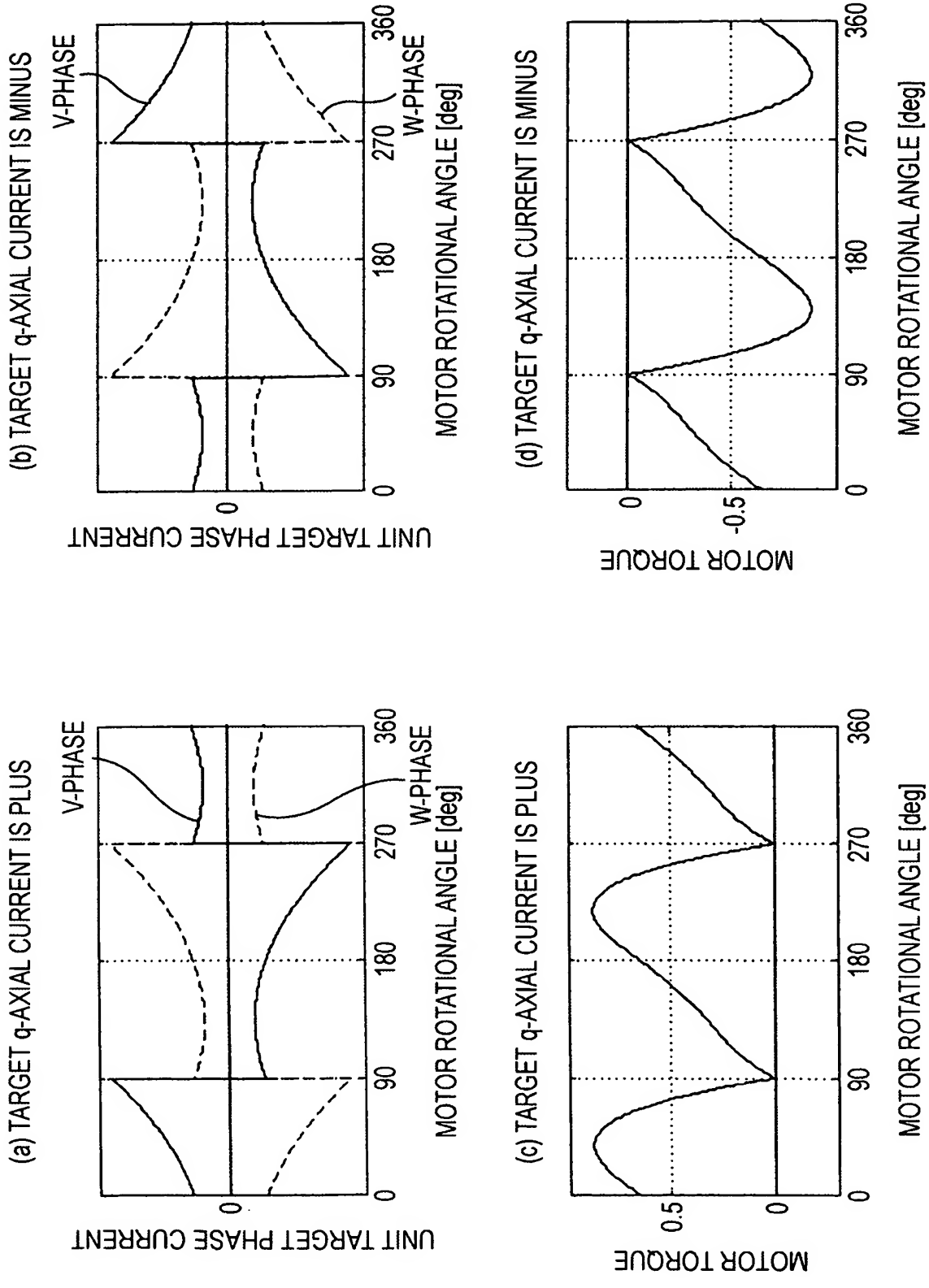
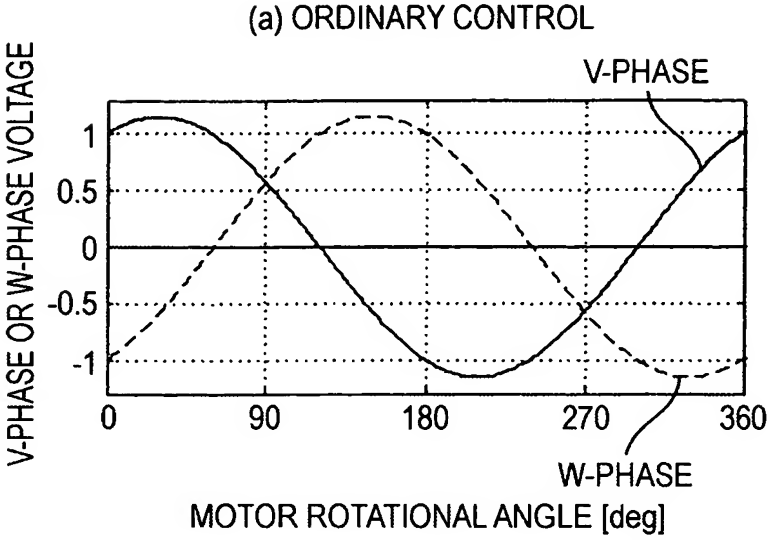

(a) TARGET q-AXIAL CURRENT IS PLUS
V-PHASE
W-PHASE
UNIT TARGET PHASE CURRENT
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]
(b) TARGET q-AXIAL CURRENT IS MINUS
V-PHASE
W-PHASE
UNIT TARGET PHASE CURRENT
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]
(c) TARGET q-AXIAL CURRENT IS PLUS
MOTOR TORQUE
0.5
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]
(d) TARGET q-AXIAL CURRENT IS MINUS
MOTOR TORQUE
0
-0.5
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]

FIG. 6


(a) ORDINARY CONTROL
V-PHASE
V-PHASE OR W-PHASE VOLTAGE
1
0.5
0
-0.5
-1
0
90
180
270
360
W-PHASE
MOTOR ROTATIONAL ANGLE [deg]

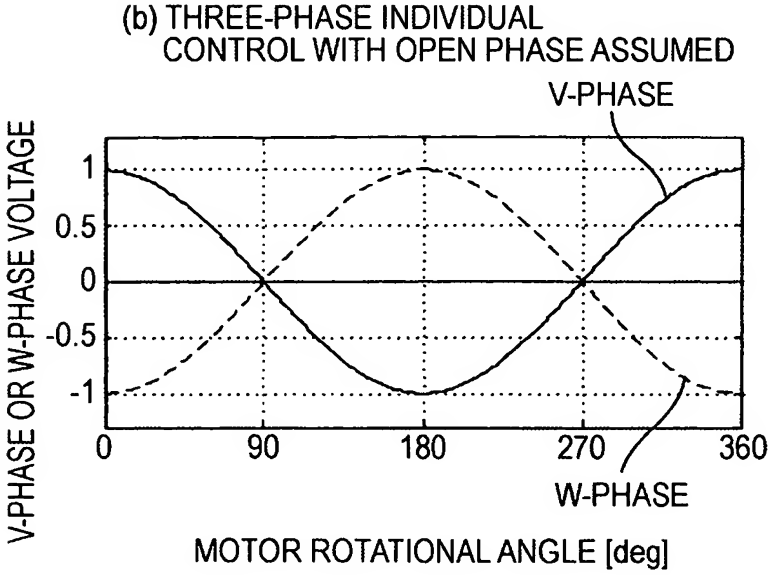

(b) THREE-PHASE INDIVIDUAL
CONTROL WITH OPEN PHASE ASSUMED
V-PHASE
V-PHASE OR W-PHASE VOLTAGE
1
0.5
0
-0.5
-1
0
90
180
270
360
W-PHASE
MOTOR ROTATIONAL ANGLE [deg]

FIG. 7

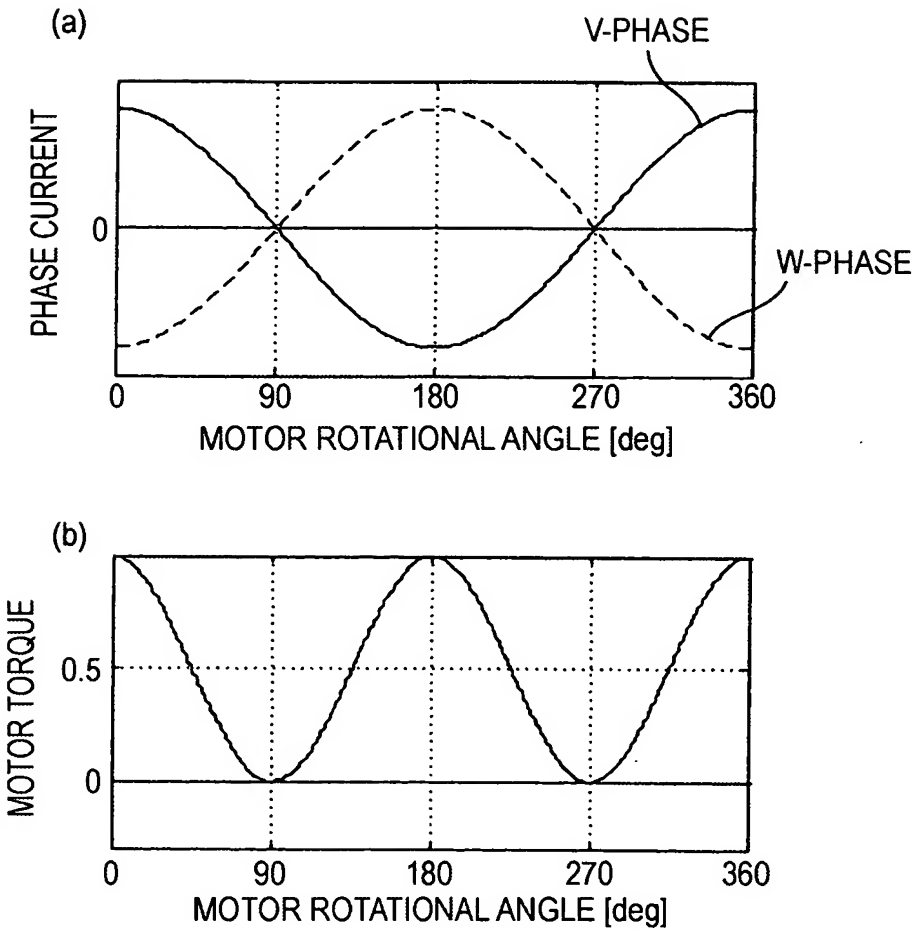

(a)
V-PHASE
W-PHASE
PHASE CURRENT
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]
(b)
MOTOR TORQUE
0.5
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]

FIG. 8

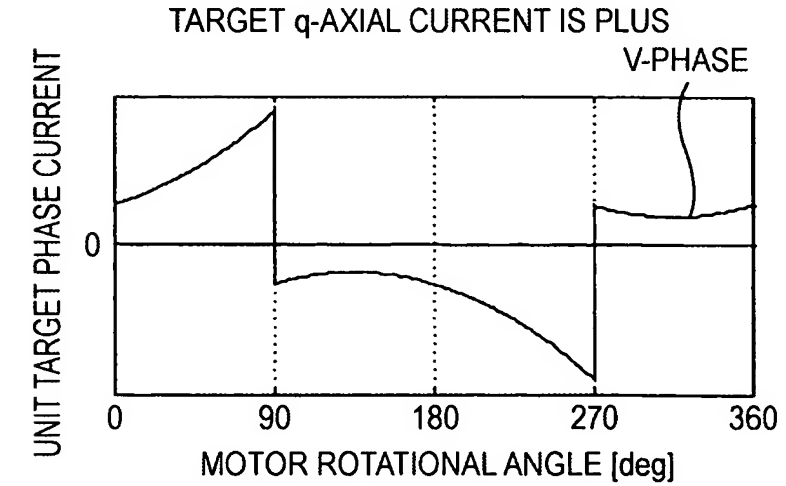

TARGET q-AXIAL CURRENT IS PLUS
V-PHASE
UNIT TARGET PHASE CURRENT
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]

FIG. 9

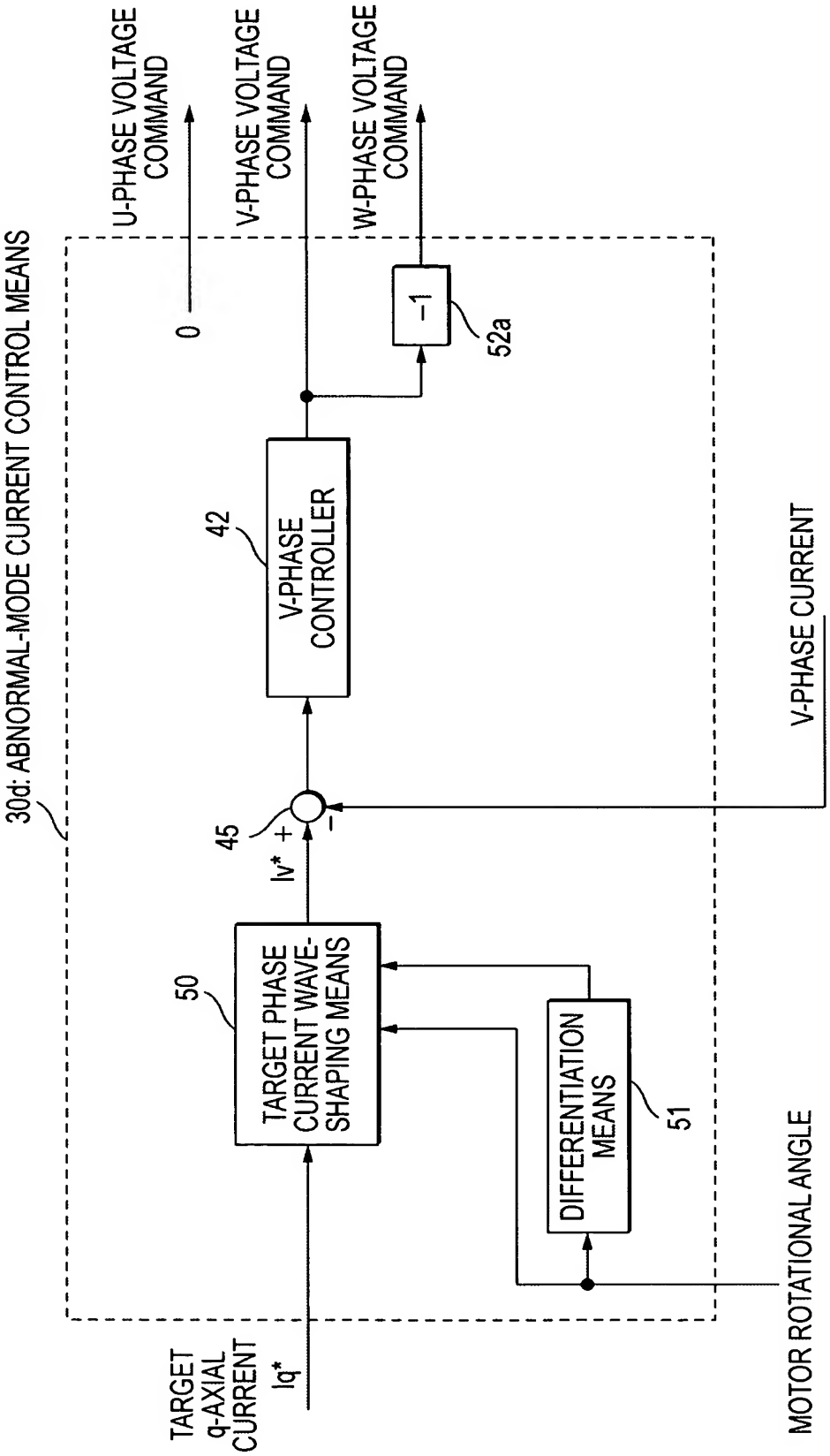

30d: ABNORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND
V-PHASE VOLTAGE COMMAND
W-PHASE VOLTAGE COMMAND
0
-1
52a
42
V-PHASE CONTROLLER
45
+
-
Iv*
V-PHASE CURRENT
50
TARGET PHASE CURRENT WAVE-SHAPING MEANS
DIFFERENTIATION MEANS
51
TARGET q-AXIAL CURRENT Iq*
MOTOR ROTATIONAL ANGLE

FIG. 10

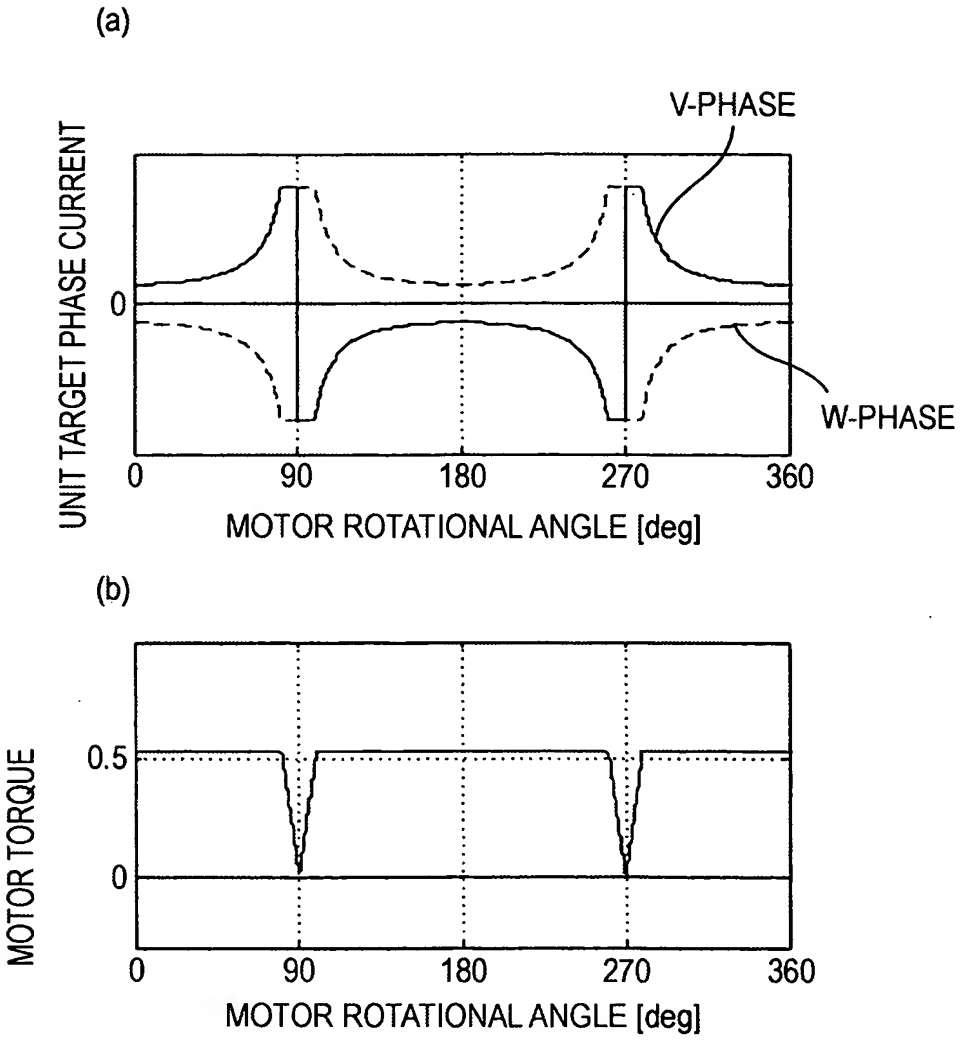

(a)
V-PHASE
W-PHASE
UNIT TARGET PHASE CURRENT
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]
(b)
MOTOR TORQUE
0.5
0
0
90
180
270
360
MOTOR ROTATIONAL ANGLE [deg]

FIG. 11

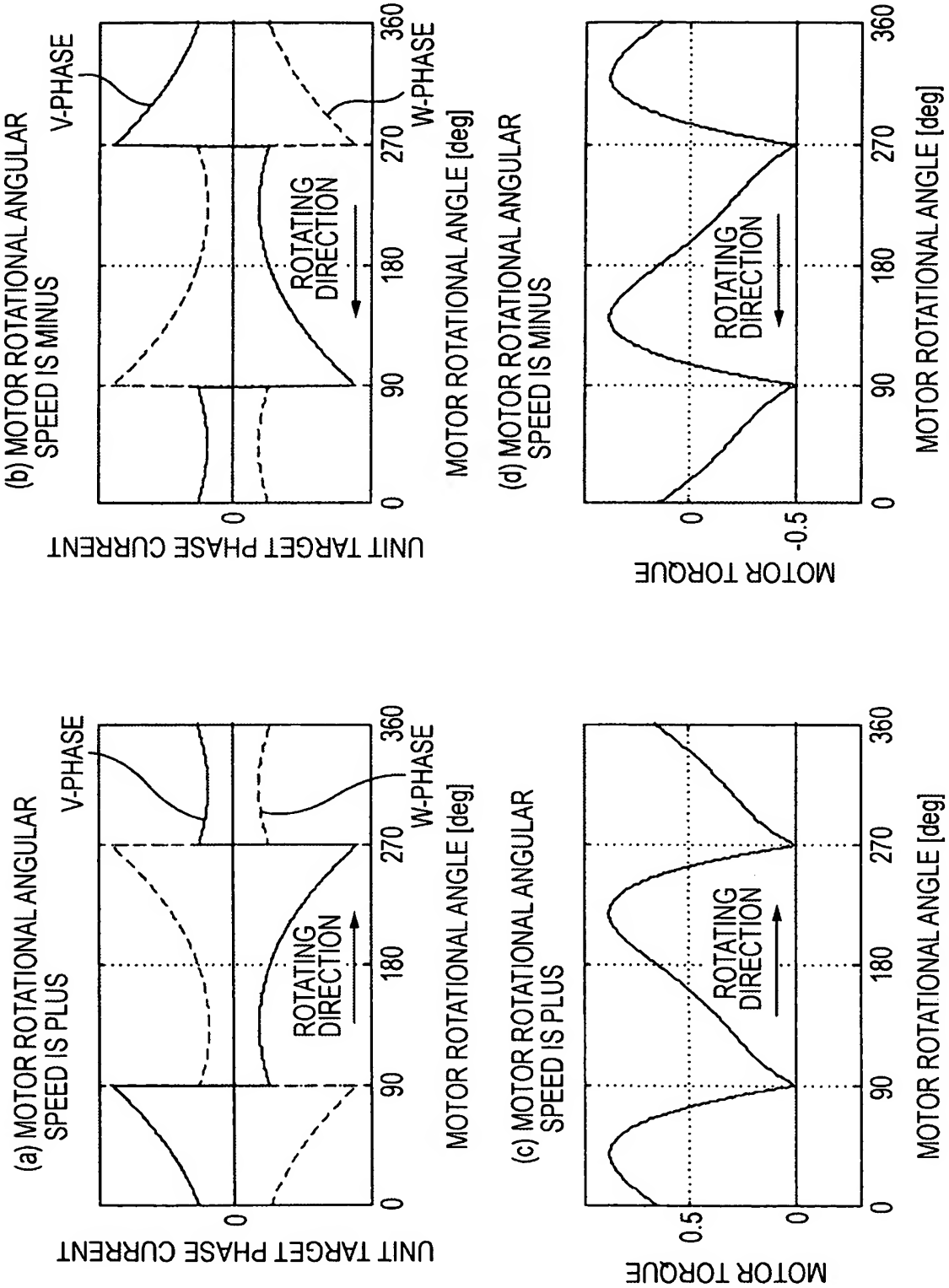

(a) MOTOR ROTATIONAL ANGULAR SPEED IS PLUS
V-PHASE
W-PHASE
ROTATING DIRECTION
UNIT TARGET PHASE CURRENT
MOTOR ROTATIONAL ANGLE [deg]
0
90
180
270
360
(b) MOTOR ROTATIONAL ANGULAR SPEED IS MINUS
V-PHASE
W-PHASE
ROTATING DIRECTION
UNIT TARGET PHASE CURRENT
MOTOR ROTATIONAL ANGLE [deg]
(c) MOTOR ROTATIONAL ANGULAR SPEED IS PLUS
ROTATING DIRECTION
MOTOR TORQUE
0.5
0
MOTOR ROTATIONAL ANGLE [deg]
(d) MOTOR ROTATIONAL ANGULAR SPEED IS MINUS
ROTATING DIRECTION
MOTOR TORQUE
0
-0.5
MOTOR ROTATIONAL ANGLE [deg]

FIG. 12

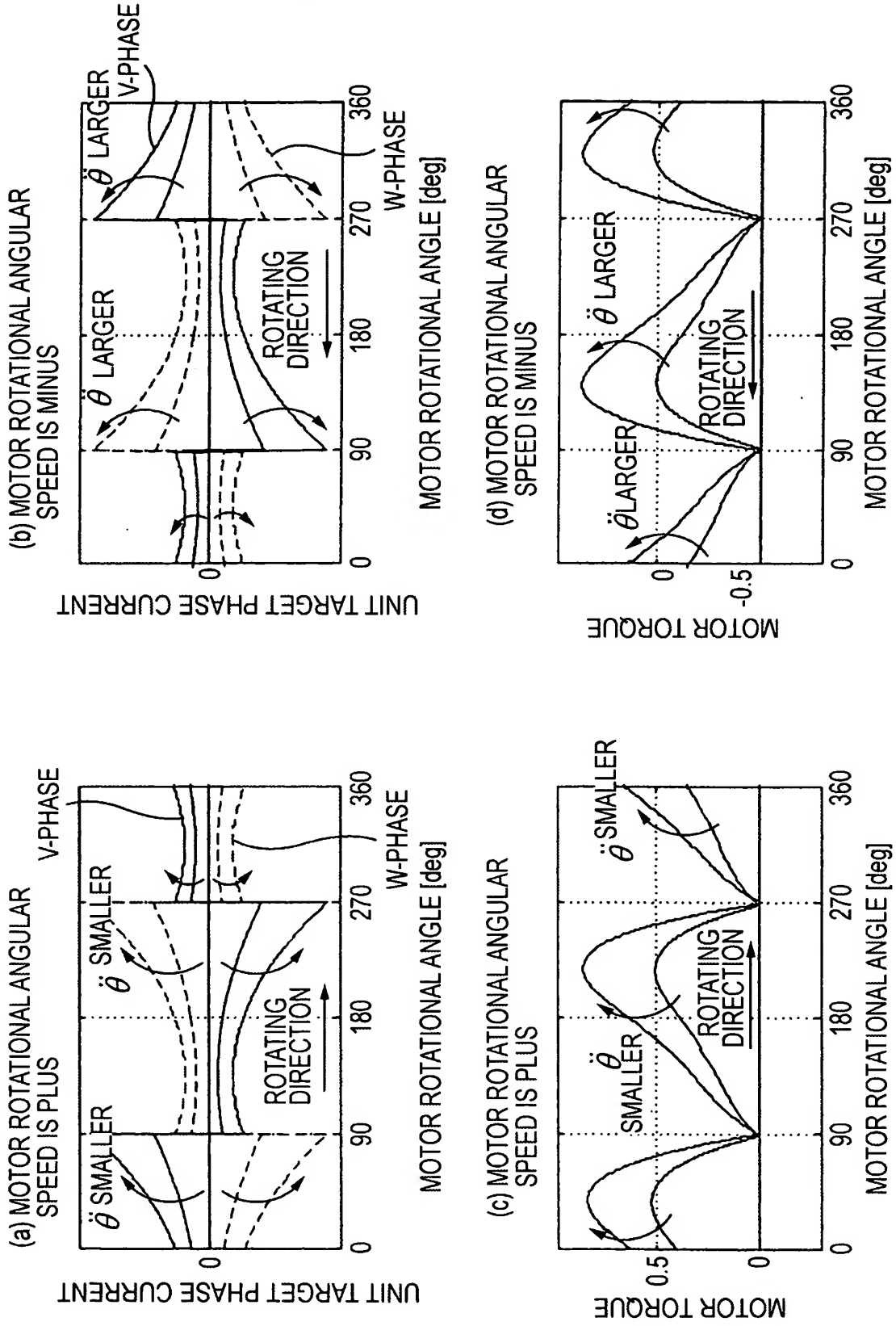
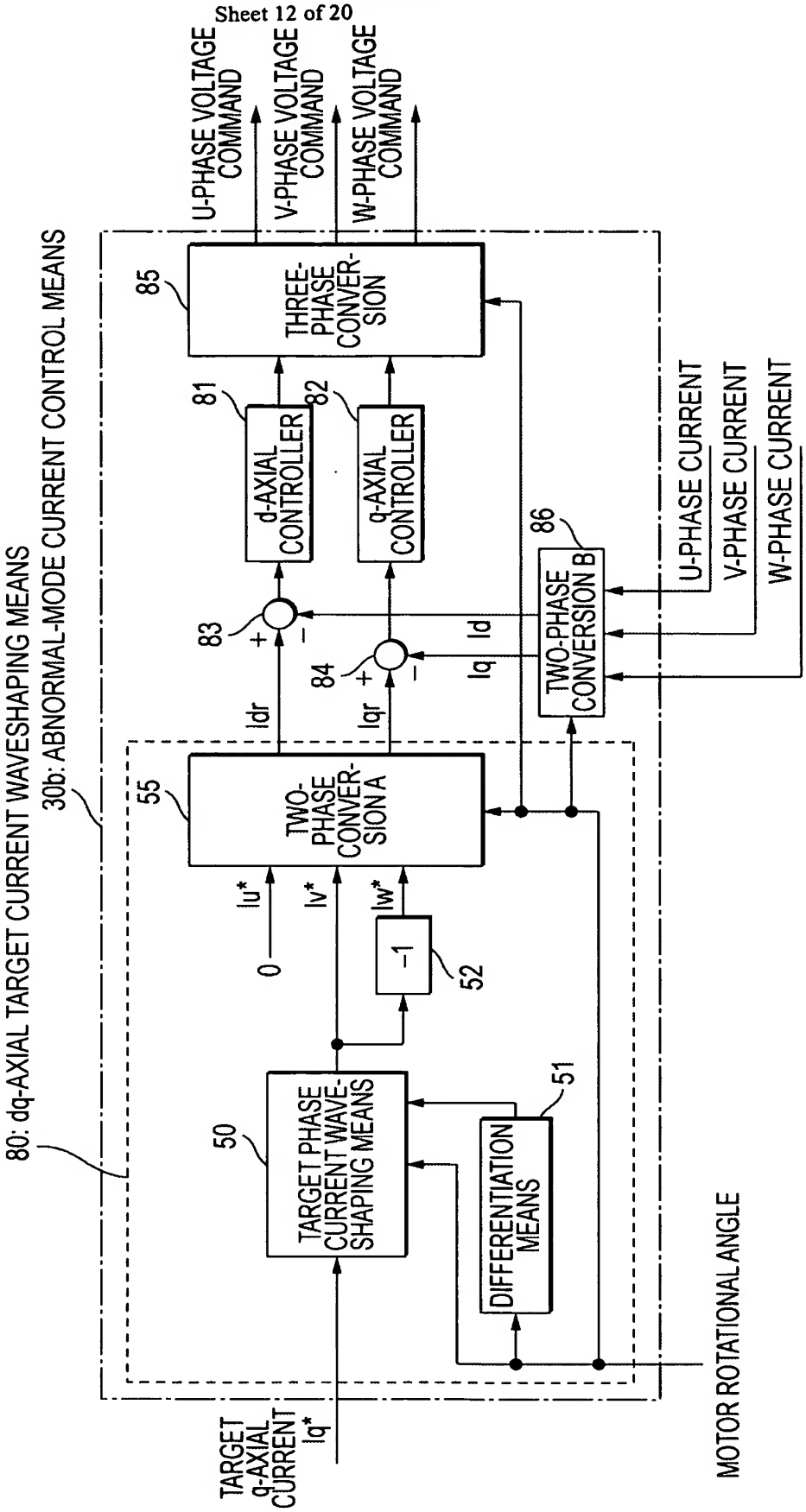

(a) MOTOR ROTATIONAL ANGULAR SPEED IS PLUS
(b) MOTOR ROTATIONAL ANGULAR SPEED IS MINUS
(c) MOTOR ROTATIONAL ANGULAR SPEED IS PLUS
(d) MOTOR ROTATIONAL ANGULAR SPEED IS MINUS
UNIT TARGET PHASE CURRENT
MOTOR TORQUE
MOTOR ROTATIONAL ANGLE [deg]
V-PHASE
W-PHASE
ROTATING DIRECTION
θ̈ SMALLER
θ̈ LARGER
0
90
180
270
360
0.5
-0.5

FIG. 13


80: dq-AXIAL TARGET CURRENT WAVESHAPING MEANS
30b: ABNORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND
V-PHASE VOLTAGE COMMAND
W-PHASE VOLTAGE COMMAND
85
THREE-PHASE CONVERSION
81
d-AXIAL CONTROLLER
82
q-AXIAL CONTROLLER
86
TWO-PHASE CONVERSION B
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
83
84
Id
Iq
Idr
Iqr
55
TWO-PHASE CONVERSION A
Iu*
Iv*
Iw*
0
-1
52
50
TARGET PHASE CURRENT WAVE-SHAPING MEANS
51
DIFFERENTIATION MEANS
TARGET q-AXIAL CURRENT Iq*
MOTOR ROTATIONAL ANGLE

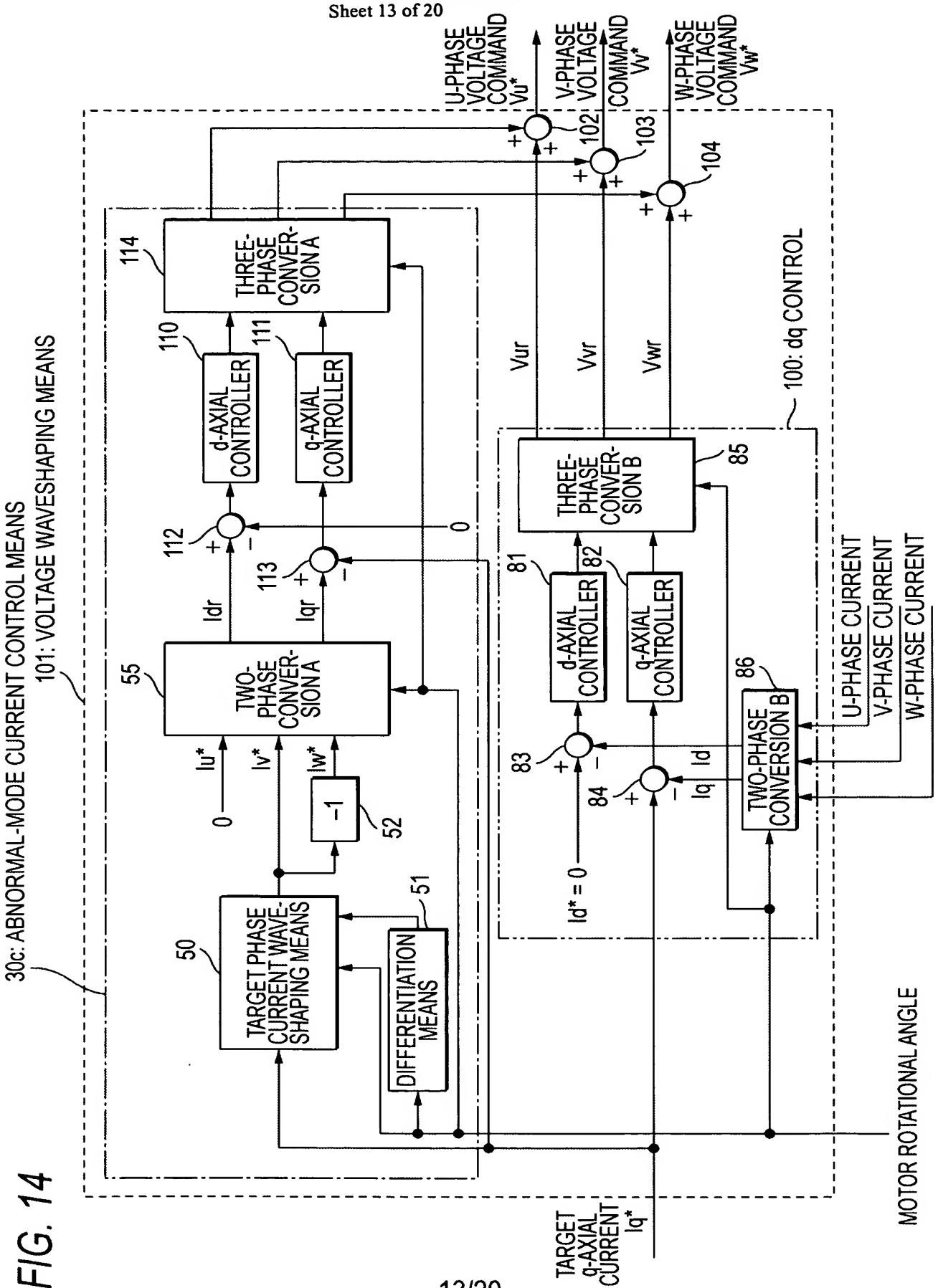

30c: ABNORMAL-MODE CURRENT CONTROL MEANS
101: VOLTAGE WAVESHAPING MEANS
100: dq CONTROL
U-PHASE VOLTAGE COMMAND Vu*
V-PHASE VOLTAGE COMMAND Vv*
W-PHASE VOLTAGE COMMAND Vw*
THREE-PHASE CONVERSION A
THREE-PHASE CONVERSION B
d-AXIAL CONTROLLER
q-AXIAL CONTROLLER
TWO-PHASE CONVERSION A
TWO-PHASE CONVERSION B
TARGET PHASE CURRENT WAVESHAPING MEANS
DIFFERENTIATION MEANS
Vur
Vvr
Vwr
Idr
Iqr
Id
Iq
Iu*
Iv*
Iw*
Id* = 0
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
MOTOR ROTATIONAL ANGLE
TARGET q-AXIAL CURRENT Iq*

FIG. 14

FIG. 15

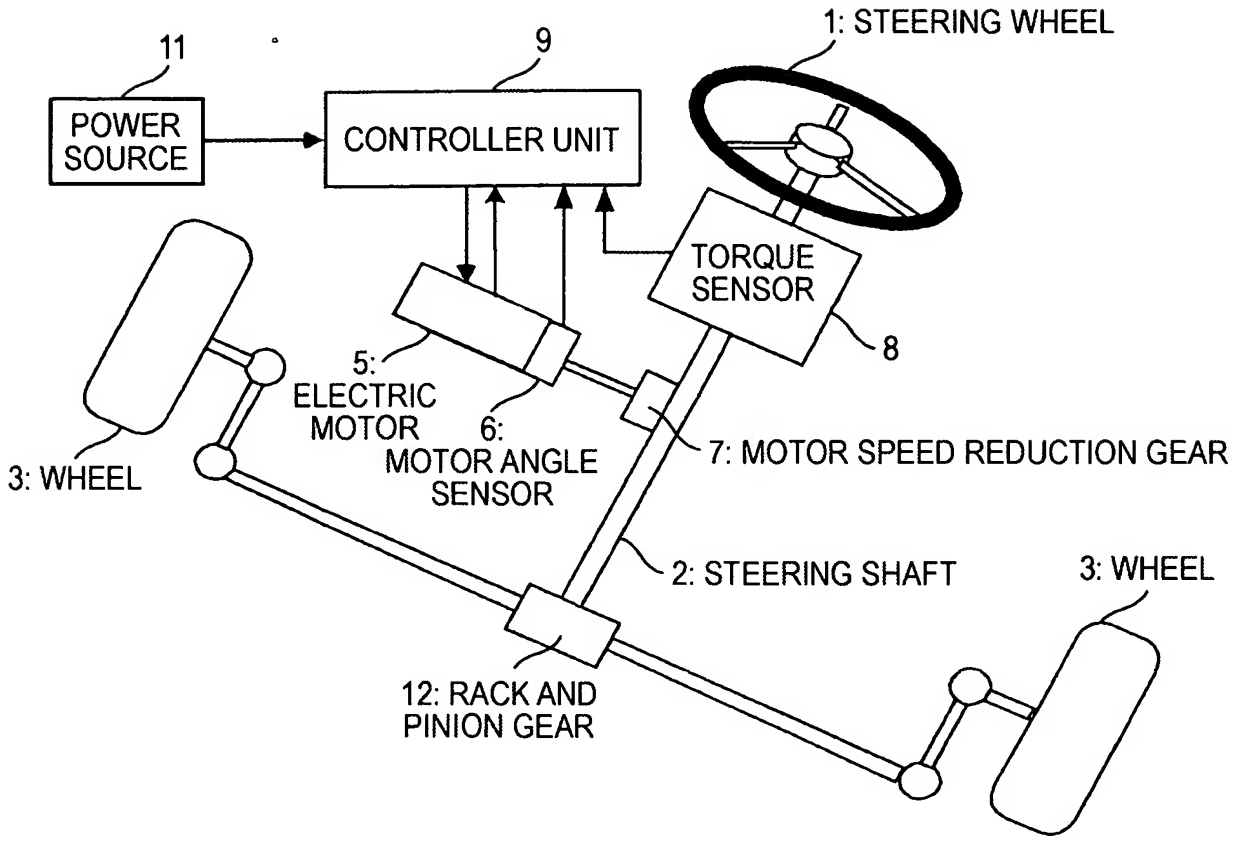

11
9
1: STEERING WHEEL
POWER SOURCE
CONTROLLER UNIT
TORQUE SENSOR
8
5: ELECTRIC MOTOR
6: MOTOR ANGLE SENSOR
7: MOTOR SPEED REDUCTION GEAR
3: WHEEL
2: STEERING SHAFT
3: WHEEL
12: RACK AND PINION GEAR

FIG. 16

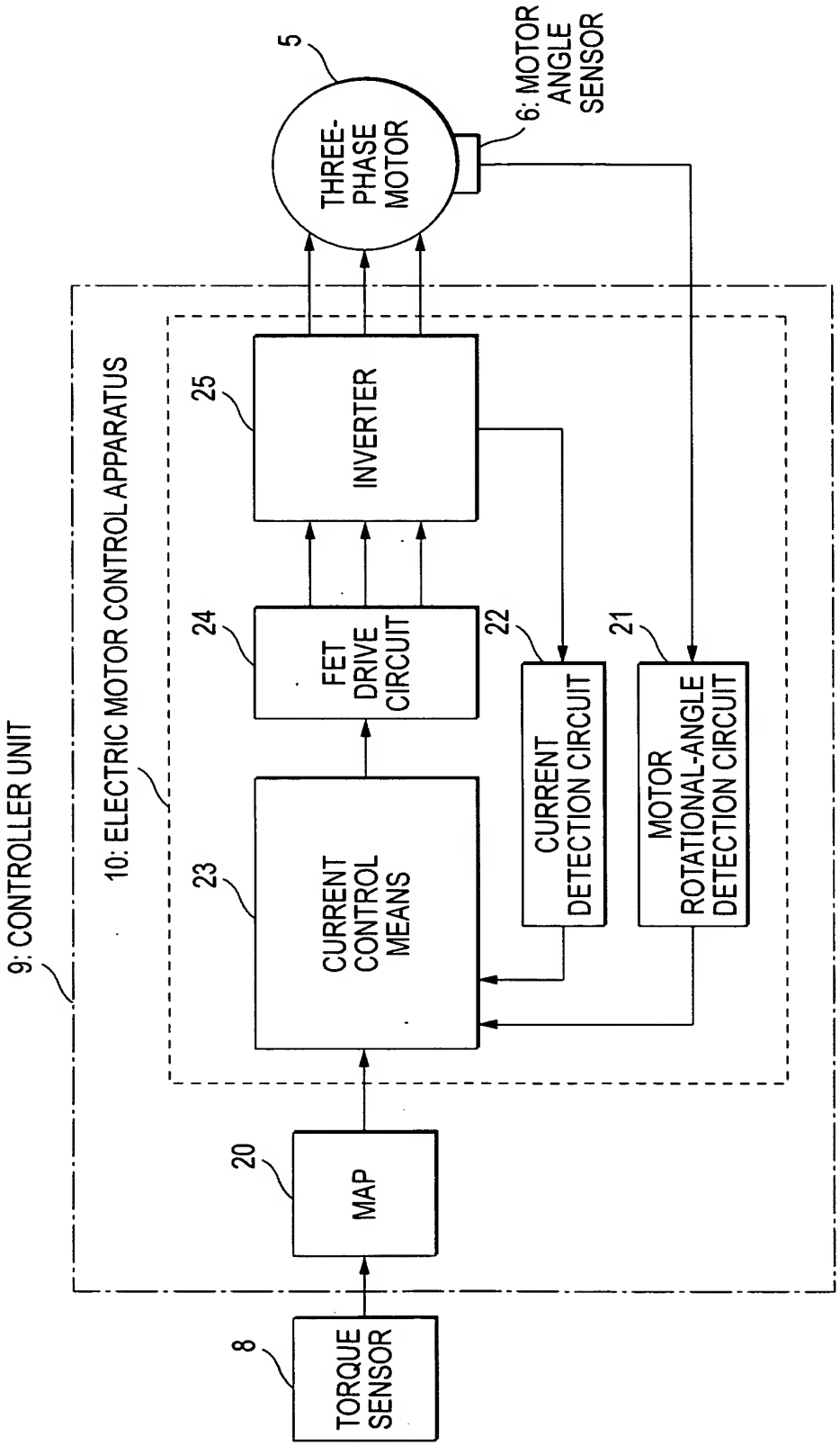

5
6: MOTOR ANGLE SENSOR
THREE-PHASE MOTOR
9: CONTROLLER UNIT
10: ELECTRIC MOTOR CONTROL APPARATUS
25
INVERTER
24
FET DRIVE CIRCUIT
22
CURRENT DETECTION CIRCUIT
21
MOTOR ROTATIONAL-ANGLE DETECTION CIRCUIT
23
CURRENT CONTROL MEANS
20
MAP
8
TORQUE SENSOR

FIG. 17

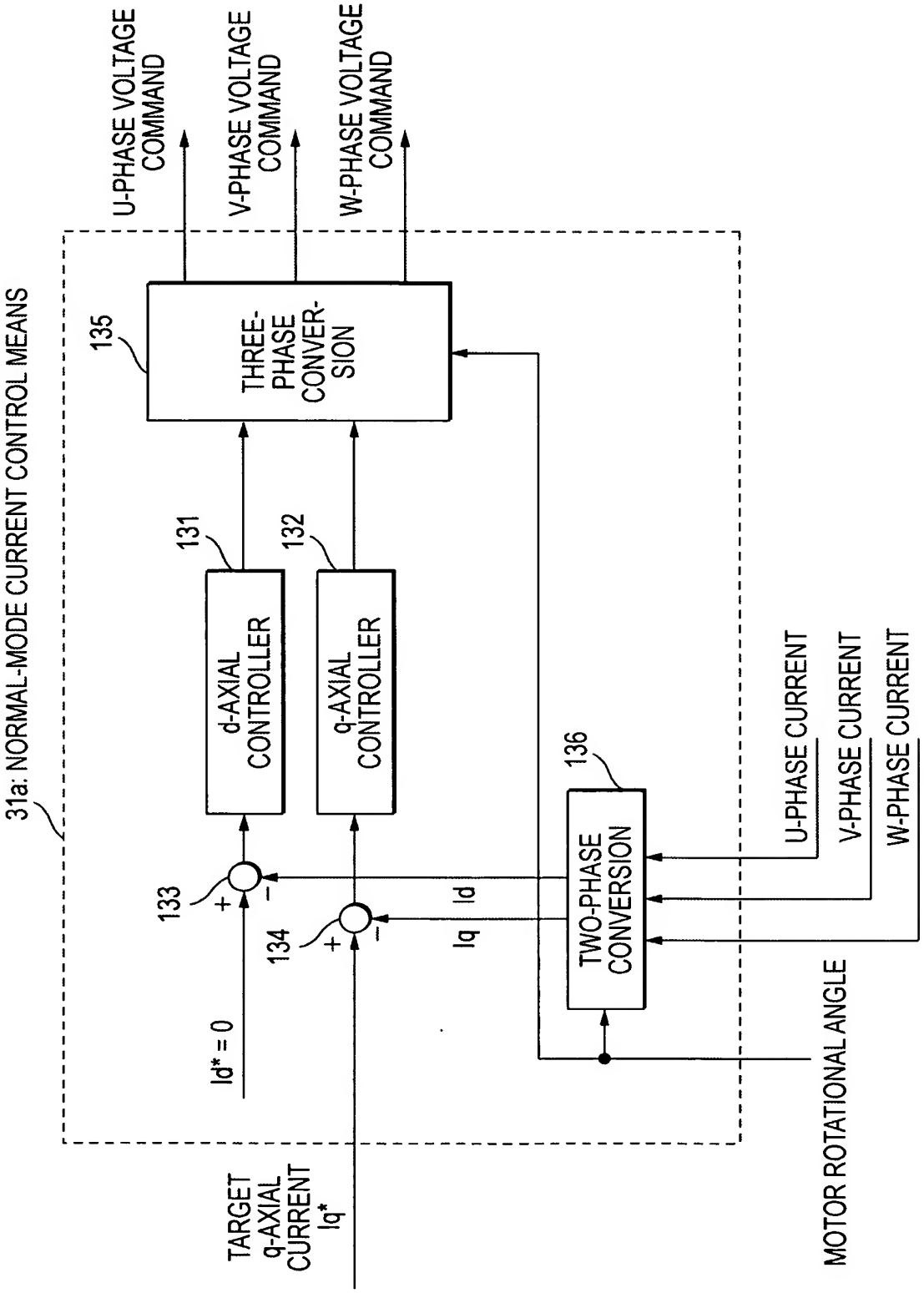

31a: NORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND
V-PHASE VOLTAGE COMMAND
W-PHASE VOLTAGE COMMAND
135
THREE-PHASE CONVER-SION
131
132
d-AXIAL CONTROLLER
q-AXIAL CONTROLLER
133
134
136
TWO-PHASE CONVERSION
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
Id
Iq
Id* = 0
TARGET q-AXIAL CURRENT Iq*
MOTOR ROTATIONAL ANGLE

FIG. 18

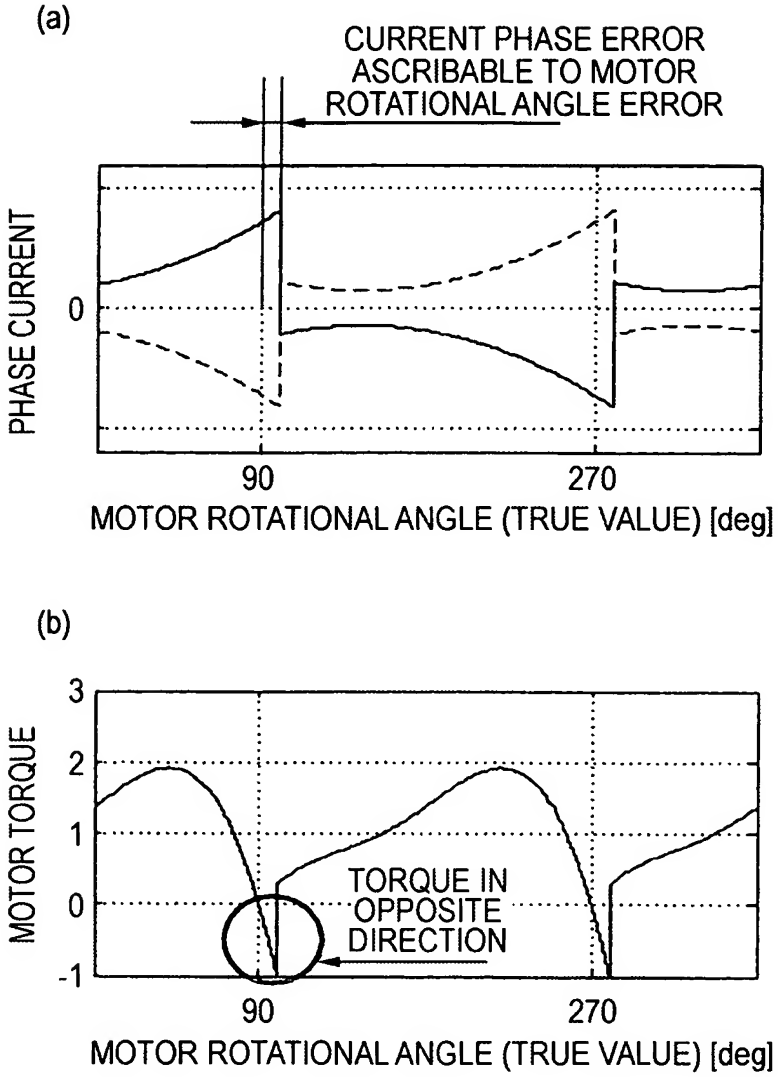

(a)
CURRENT PHASE ERROR ASCRIBABLE TO MOTOR ROTATIONAL ANGLE ERROR
PHASE CURRENT
0
90
270
MOTOR ROTATIONAL ANGLE (TRUE VALUE) [deg]
(b)
MOTOR TORQUE
3
2
1
0
-1
TORQUE IN OPPOSITE DIRECTION
90
270
MOTOR ROTATIONAL ANGLE (TRUE VALUE) [deg]

FIG. 19

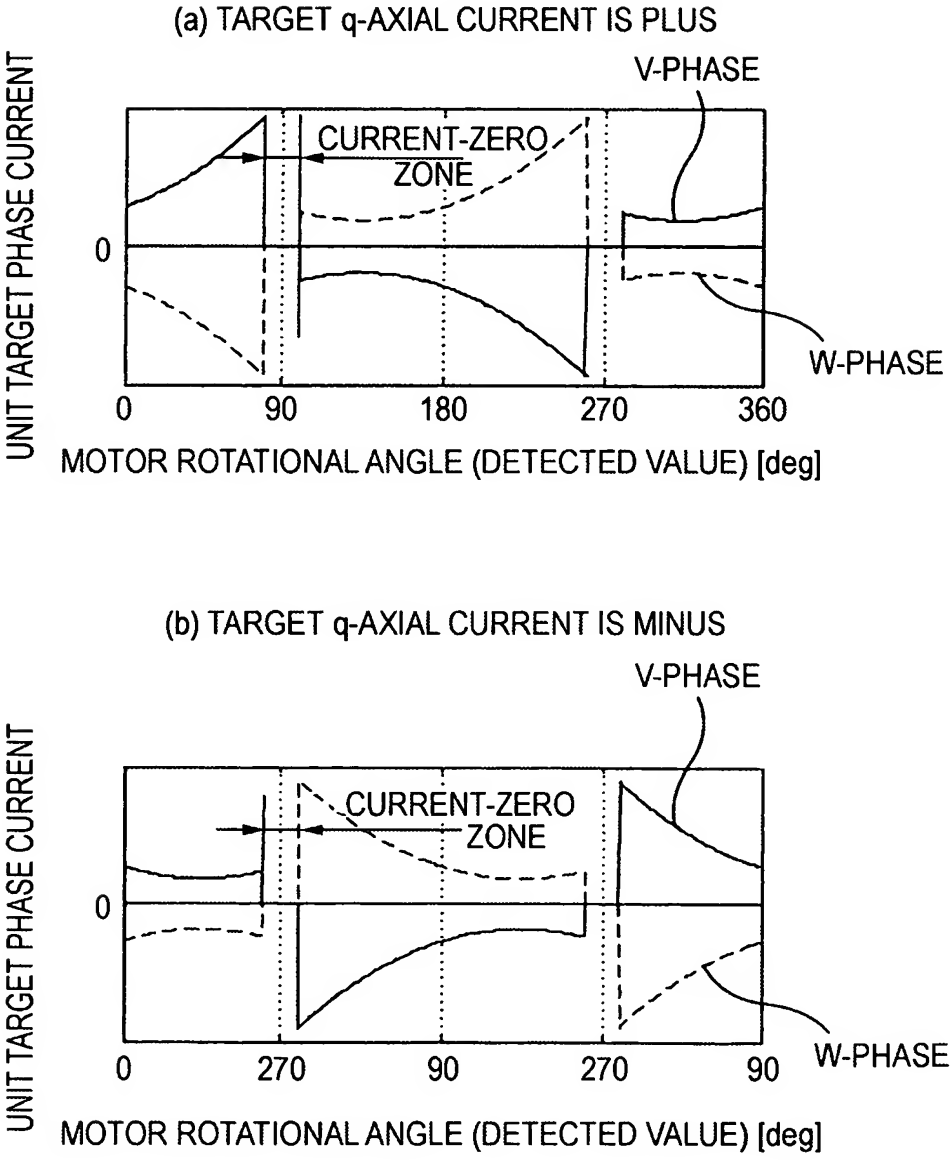

(a) TARGET q-AXIAL CURRENT IS PLUS
V-PHASE
CURRENT-ZERO ZONE
0
W-PHASE
0
90
180
270
360
UNIT TARGET PHASE CURRENT
MOTOR ROTATIONAL ANGLE (DETECTED VALUE) [deg]
(b) TARGET q-AXIAL CURRENT IS MINUS
V-PHASE
CURRENT-ZERO ZONE
0
W-PHASE
0
270
90
270
90
UNIT TARGET PHASE CURRENT
MOTOR ROTATIONAL ANGLE (DETECTED VALUE) [deg]

FIG. 20

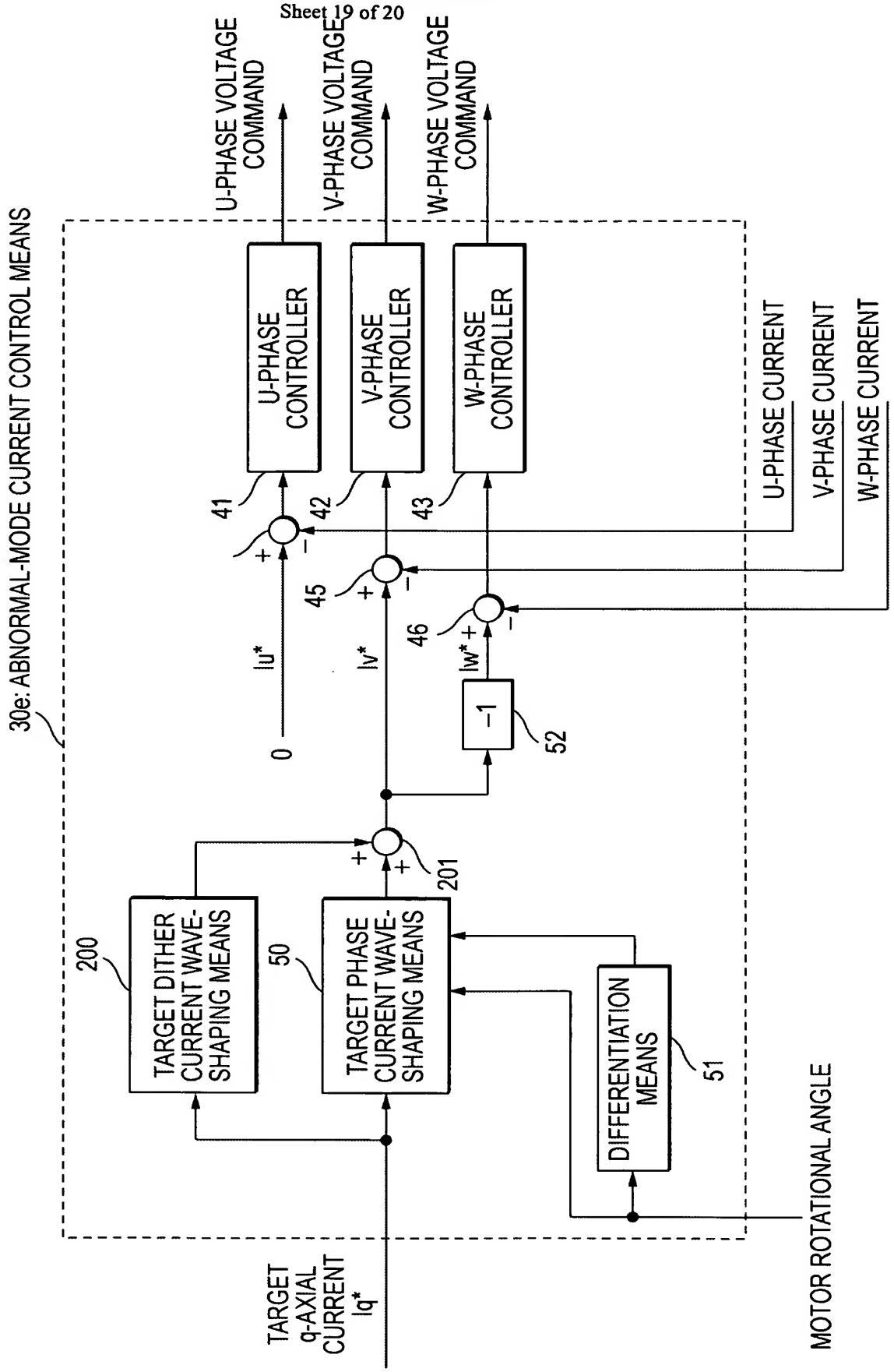
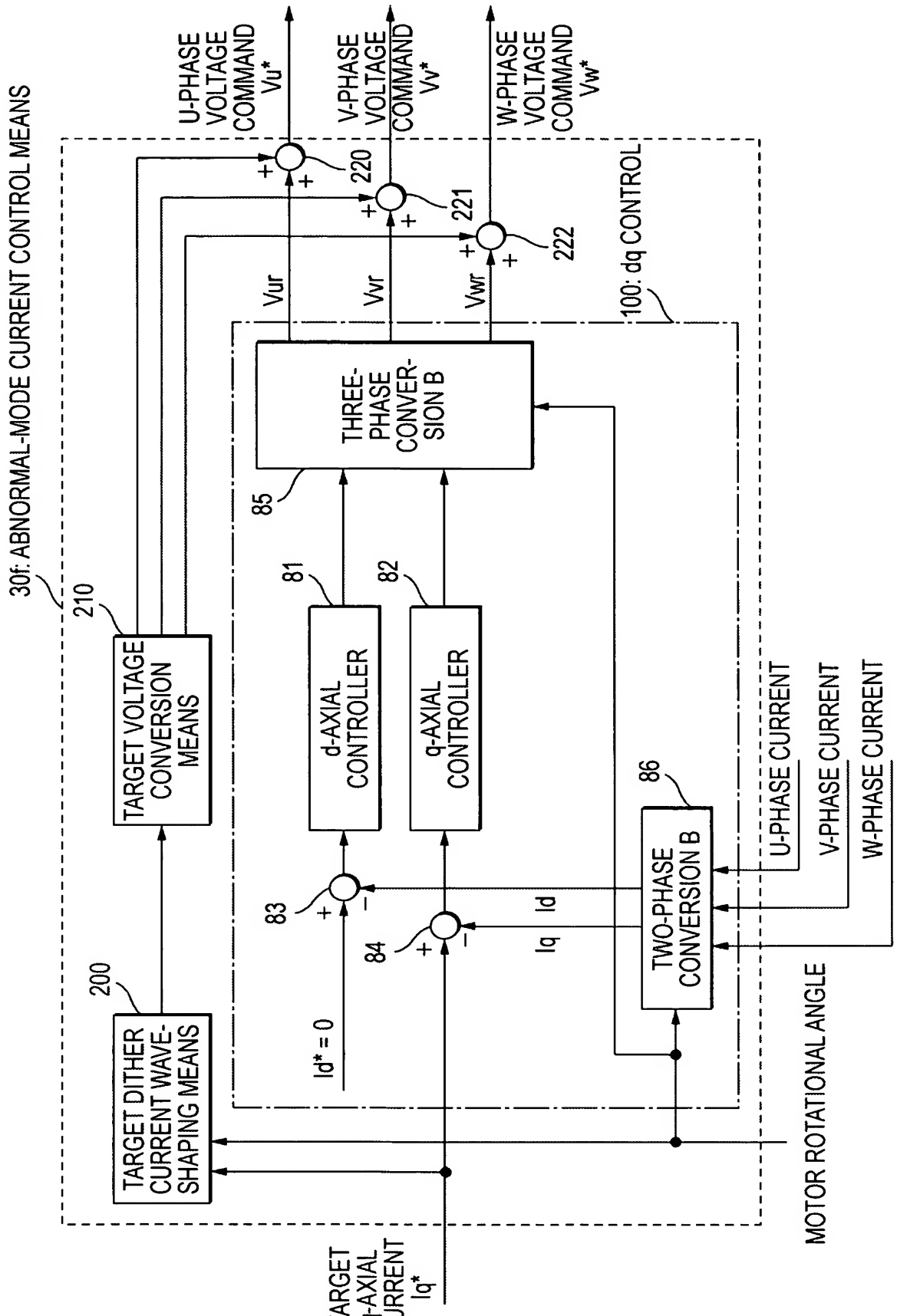

30e: ABNORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND
V-PHASE VOLTAGE COMMAND
W-PHASE VOLTAGE COMMAND
U-PHASE CONTROLLER
V-PHASE CONTROLLER
W-PHASE CONTROLLER
41
42
43
45
46
52
-1
0
Iu*
Iv*
Iw*
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
201
200
50
51
TARGET DITHER CURRENT WAVE-SHAPING MEANS
TARGET PHASE CURRENT WAVE-SHAPING MEANS
DIFFERENTIATION MEANS
TARGET q-AXIAL CURRENT Iq*
MOTOR ROTATIONAL ANGLE

FIG. 21


30f: ABNORMAL-MODE CURRENT CONTROL MEANS
U-PHASE VOLTAGE COMMAND Vu*
V-PHASE VOLTAGE COMMAND Vv*
W-PHASE VOLTAGE COMMAND Vw*
220
221
222
Vur
Vvr
Vwr
100: dq CONTROL
THREE-PHASE CONVER-SION B
85
81
82
210
TARGET VOLTAGE CONVERSION MEANS
d-AXIAL CONTROLLER
q-AXIAL CONTROLLER
86
TWO-PHASE CONVERSION B
U-PHASE CURRENT
V-PHASE CURRENT
W-PHASE CURRENT
83
84
Id
Iq
200
TARGET DITHER CURRENT WAVE-SHAPING MEANS
Id* = 0
MOTOR ROTATIONAL ANGLE
TARGET q-AXIAL CURRENT Iq*